# Unit 8
# Plant Form and Function
## Chapter 28: Plant Structure and Growth

# Angiosperms Comparison

| Monocots | Eudicots |
|---|---|
| One cotyledon | Two cotyledons |
| Parallel veins | Netlike veins |
| Scattered vascular tissue | Ring of vascular tissue |
| Fibrous roots | Taproot |
| Floral organs in multiples of 3 | Floral organs in multiples of 4 or 5 |
| Ex: Grasses (wheat, corn, rice), orchids, lilies | Ex: Beans, sunflowers, maples, oaks |

# Plant organs:  Roots, Stems, and Leaves

- Roots:  anchor, absorb water/minerals, store carbs
  - Taproot system
    - Taller plants
    - Better light access and pollen/seed dispersal
  - Fibrous root system
    - Small or trailing plants
    - Good for preventing erosion
  - Also **root hairs**
    - Increase surface area for absorption

- Stems: elongate  and orient shoots to maximize photosynthesis by leaves; elevate reproductive structures
  - **Apical buds**
    - Located near the shoot tip (terminal)
    - Causes elongation of a young shoot
  - **Axillary buds**
    - Located in upper angle between leaf and stem
    - Can form a lateral branch, thorn, or flower
    - Generally dormant

- Leaves: photosynthesis, gas exchange, defense, heat loss
  - **Stomata** = Pores in epidermis of leaves
    - Allow $CO_2$ and $O_2$
    - Major avenues for evaporative water loss
  - **Guard cells** = regulate opening and closing of stomata
  - **Mesophyll** = ground tissue in leaves
    - *Palisade mesophyll* (upper)
      - Packed for photosynthesis
    - *Spongy mesophyll (lower)*
      - Loose for gas exchange

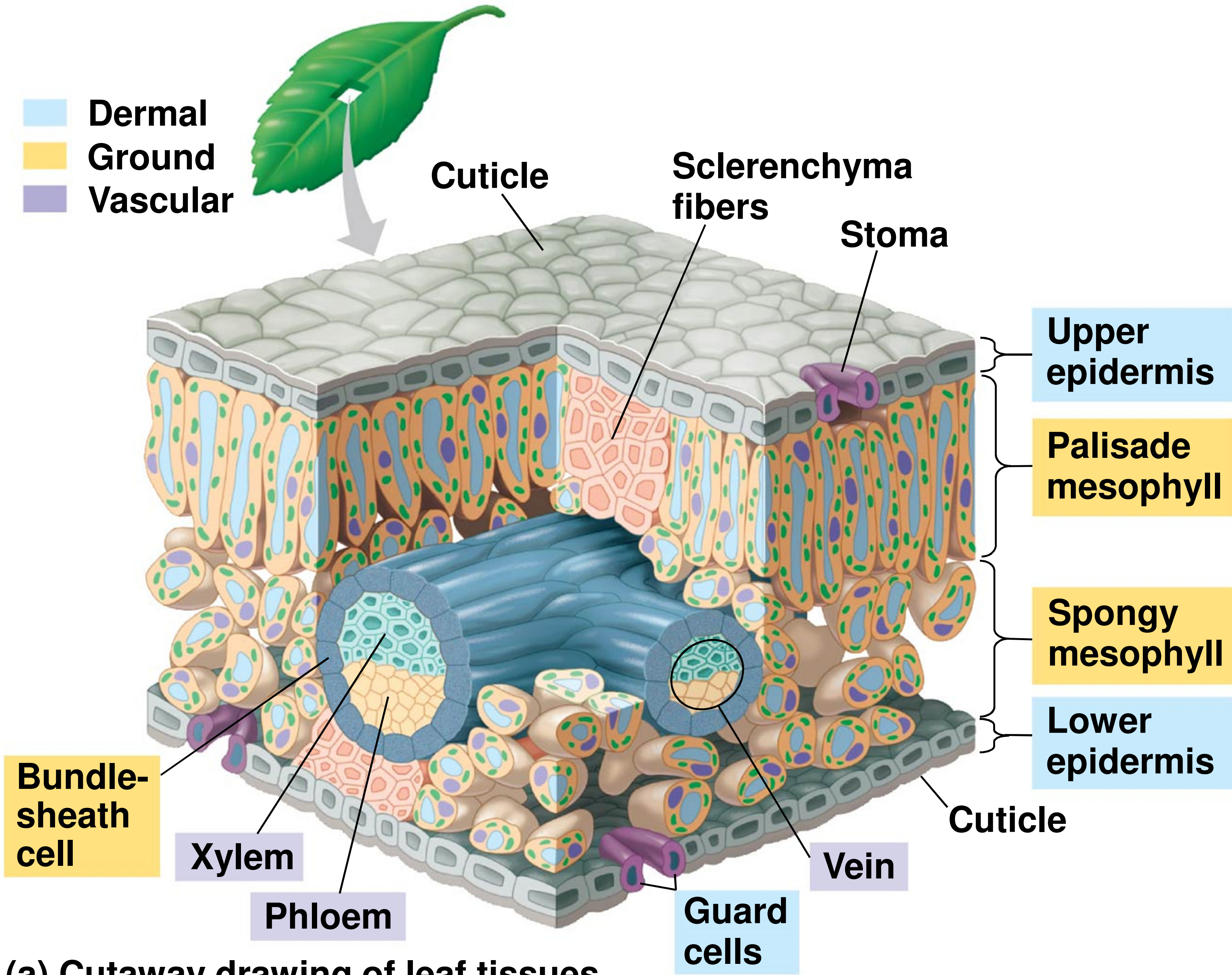
# Plant Tissues: Dermal, Vascular, and Ground

- **Dermal tissue system** = outer protective covering
  - AKA: First line of defense!
  - **Epidermis** (in nonwoody plants)
    - **Cuticle** = waxy coating that helps prevent water loss
    - **Trichomes** = hair-like outgrowths that can help with insect defense
  - **Periderm** (in woody plants)

- **Vascular tissue system** = facilitates transport of materials through the plant and provides support
  - **Xylem** transports water and dissolved minerals
  - **Phloem** transports sugars

- **Ground tissue system** = neither dermal nor vascular
  - **Pith** = internal to the vascular tissue
  - **Cortex** = external to the vascular tissue

Figure 28.17a




(a) Cutaway drawing of leaf tissues

# Types of Plant Cells

- **Parenchyma cells**
  - Relatively unspecialized
  - Store and produce organic molecules
  - Most common
- **Collenchyma cells**
  - Provide flexible support for young parts without restraining growth
- **Sclerenchyma cells**
  - Support!
  - Rigid, thick secondary walls
  - Cannot elongate

- Water-conducting cells of the **xylem**
  - Dead at functional maturity
  - Includes
    - **Tracheids**
    - **Vessel elements**
- Sugar-conducting cells of the **phloem**
  - Alive at functional maturity
  - Includes
    - **Sieve-tube elements**
    - **Companion cells**

# Plant Growth

- **Determinate growth** = growth stops at a certain size
  - Most animals
  - Some plant organs (leaves, thorns, flowers)
- **Indeterminate growth** = growth throughout a plants life
  - Enabled by **meristems** = undifferentiated tissues
    - Divide when conditions permit

- There are two main types of meristems
  1. **Apical meristems**
     - Located at the tips of roots and shoots and at the axillary buds of shoots
     - Enable **primary growth**
       - Growth in <u>length</u>
  2. **Lateral meristems**
     - Enable **secondary growth**
       - Adds <u>thickness</u> to woody plants
     - There are two lateral meristems:
       - **Vascular cambium** = adds secondary xylem and phloem (transport)
       - **Cork cambium** = replaces epidermis with periderm (protection)

Figure 28.10

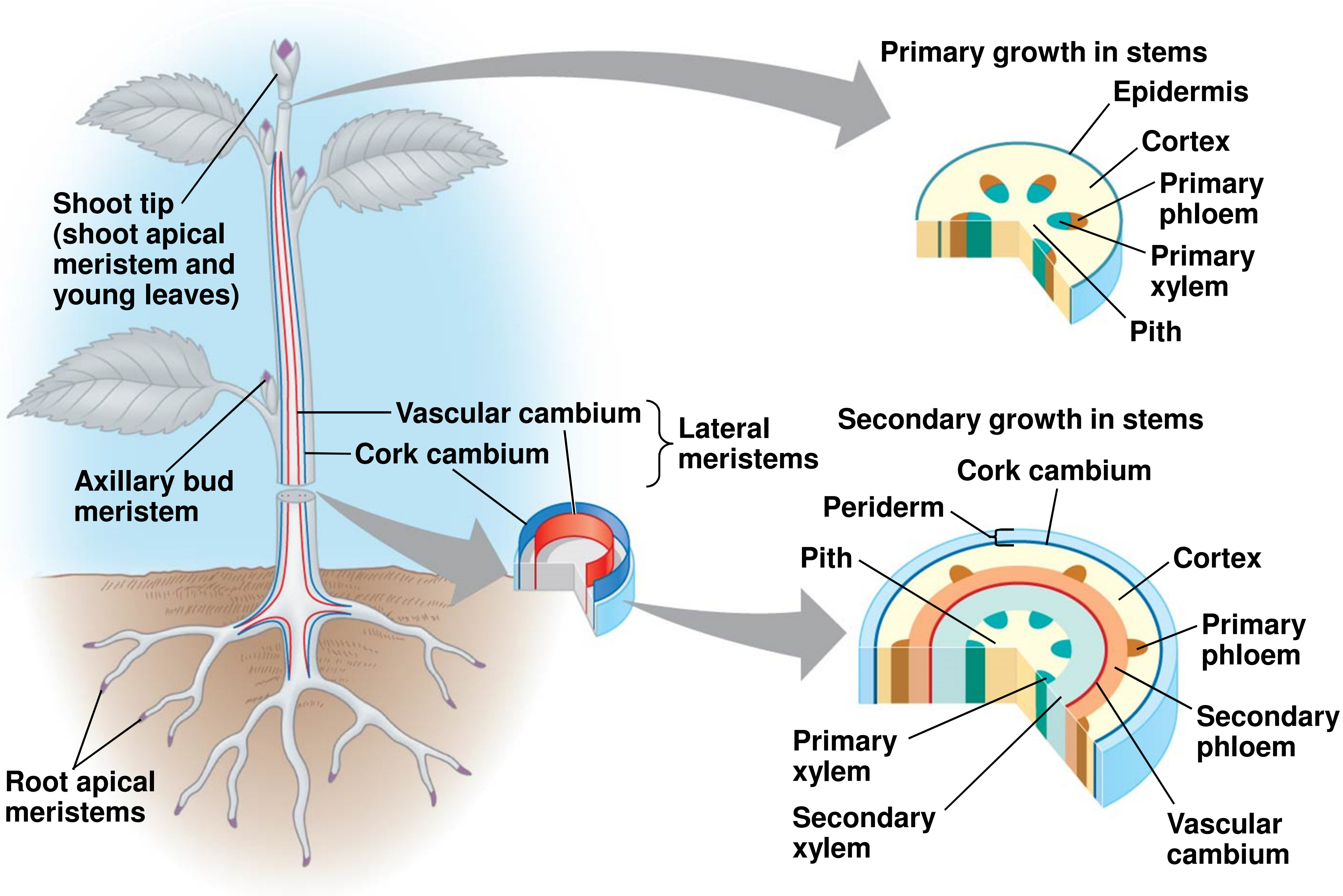
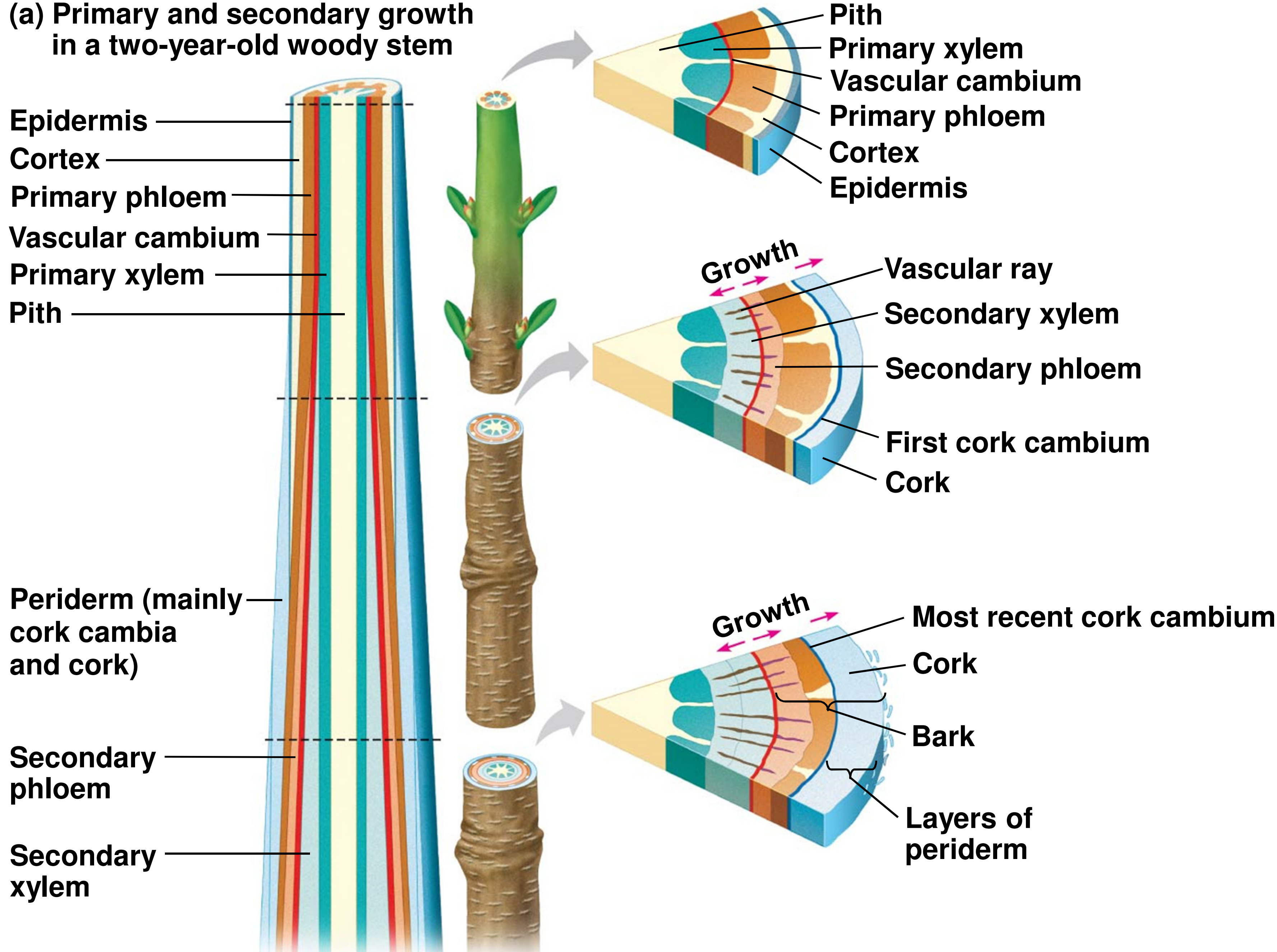

Shoot tip
(shoot apical
meristem and
young leaves)
Axillary bud
meristem
Root apical
meristems
Vascular cambium
Cork cambium
Lateral
meristems
Primary growth in stems
Epidermis
Cortex
Primary
phloem
Primary
xylem
Pith
Secondary growth in stems
Cork cambium
Periderm
Pith
Cortex
Primary
phloem
Secondary
phloem
Vascular
cambium
Primary
xylem
Secondary
xylem

Figure 28.19a-3

(a) Primary and secondary growth in a two-year-old woody stem



- Flower formation involves a transition from vegetative growth to reproductive growth
  - Production of flowers, fruits, and seeds
    - *Annuals* complete their life cycle within a year
    - *Perennials* live for many years
- It is triggered by a combination of environmental cues and internal signals
  - Day length and hormones
- Reproductive growth is determinate
  - The production of a flower stops primary growth of that shoot

## Primary Growth of Roots

- The root tip is covered by a **root cap**
  - Protects the apical meristem as the root pushes through soil
- Growth occurs just behind the root tip, in three zones of cells
  - *Zone of cell division*
    - Includes root apical meristem and its derivatives
  - *Zone of elongation*
    - Most of the growth occurs as root cells elongate
  - *Zone of differentiation*, or maturation
    - Become distinct cell types

# Unit 8
# Plant Form and Function

## Chapter 29: Resource Acquisition, Nutrition, and Transport in Vascular Plants

# Evolution of Terrestrial Plants

- Natural selection favors plants with certain adaptations
  - Height
  - Flat appendages
  - Branching roots
  - Efficient transport
- Compromises between maximizing photosynthesis and minimizing water loss

# Roots and Mutualism

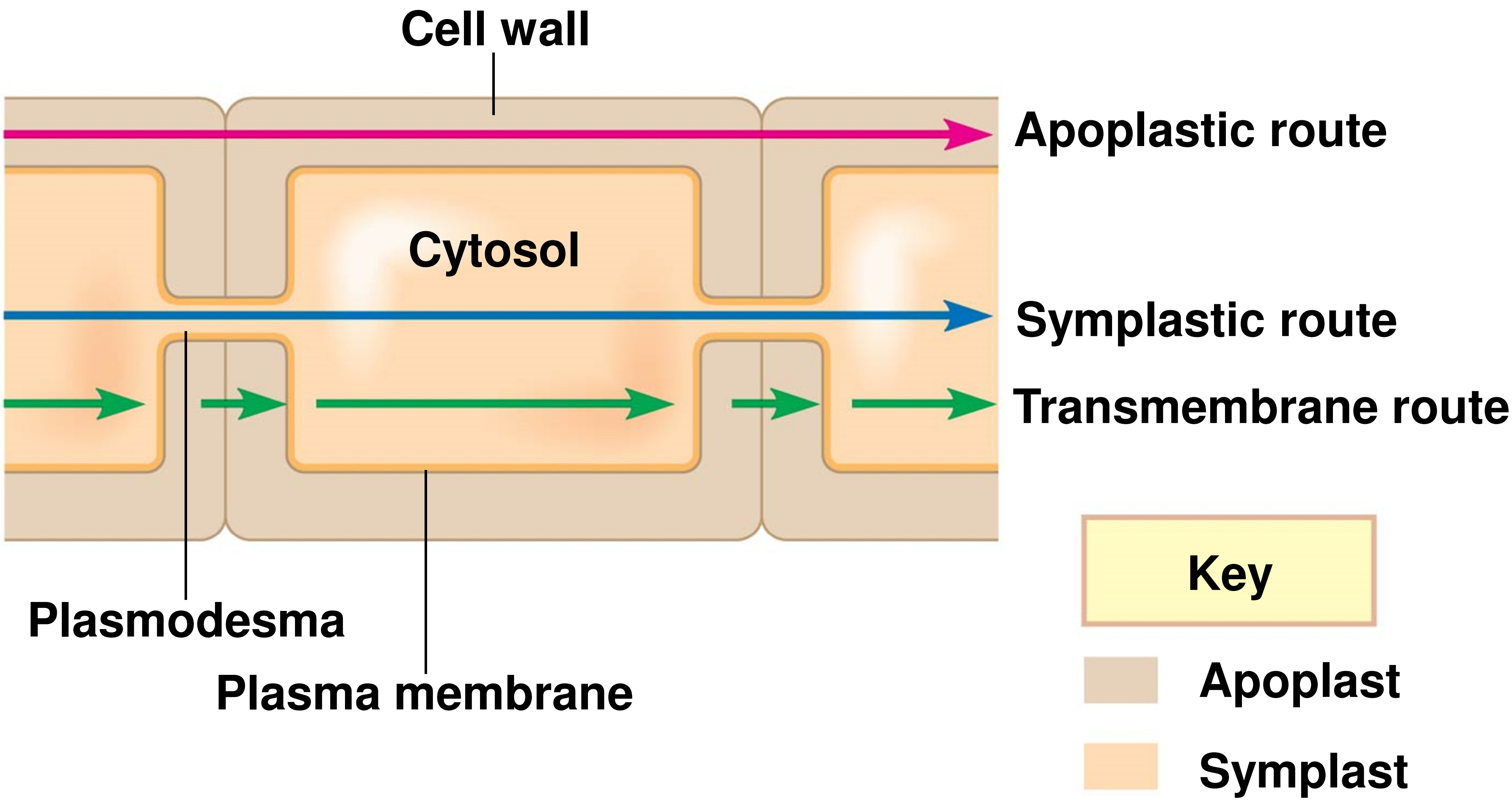
- **Mycorrhizae** are mutualistic associations of fungi and roots (increased surface area)
- Bacteria living in soil and/or plant roots may benefit plants by
  - Converting nitrogen gas to a more usable form
    - **Nitrogen fixation**
    - Ex: *Rhizobium* bacteria
  - Producing hormones that stimulate plant growth
  - Producing antibiotics that protect roots from disease
  - Absorbing toxic metals or make nutrients more available to roots
- Bacteria receives sugar and anaerobic environment

# Transport Pathways

- There are two major transport pathways through plants
  - The **apoplast**
    - Consists of everything external to the plasma membrane
    - Includes cell walls, extracellular spaces, and the interior of vessel elements and tracheids
  - The **symplast**
    - Consists of the cytosol of the living cells in a plant, as well as the plasmodesmata

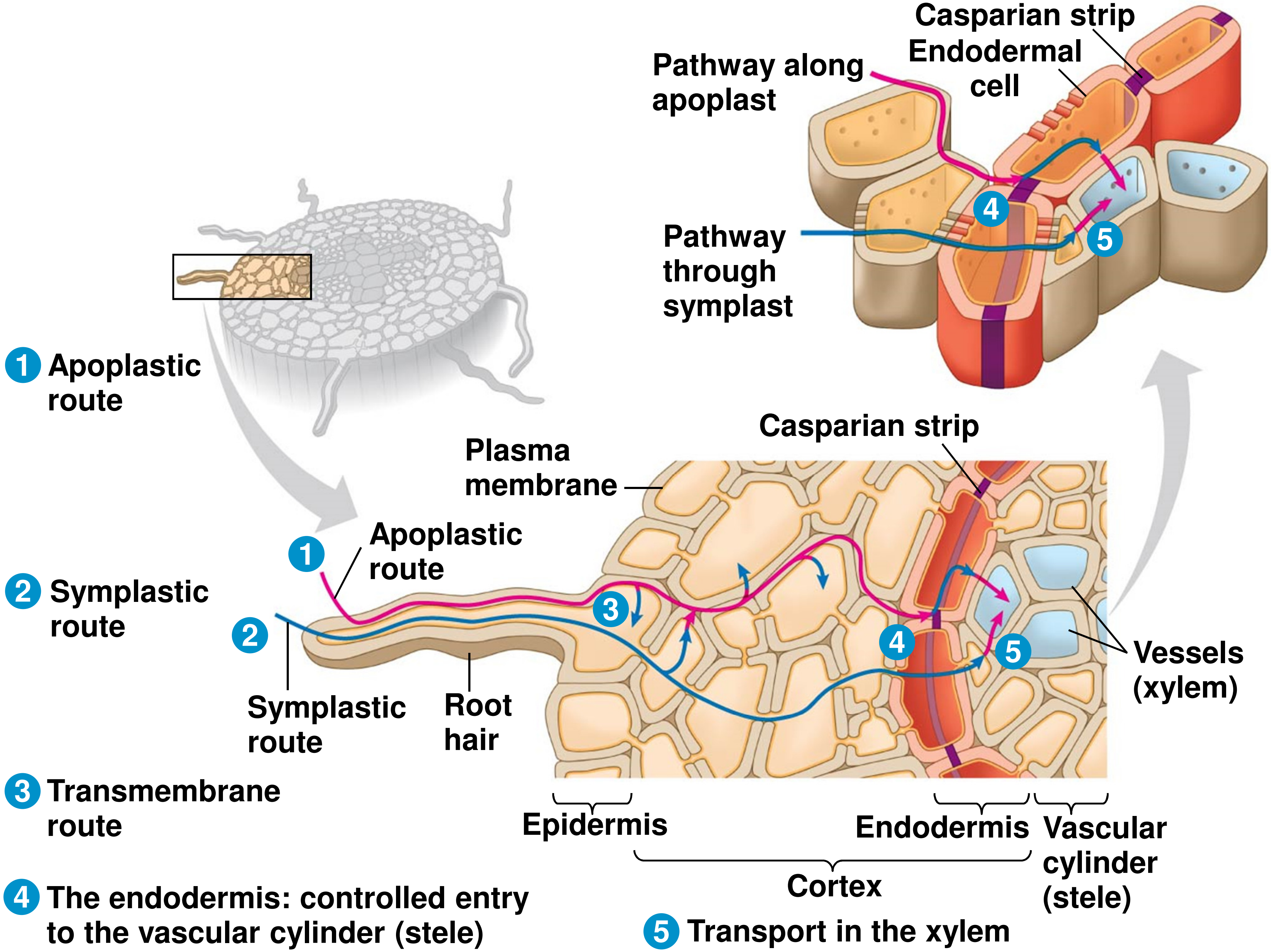
- Three transport routes for water and solutes are
  - The ***apoplastic route***
    - Through cell walls and extracellular spaces
  - The ***symplastic route***
    - Through the cytosol
    - Requires substances to cross a plasma membrane once but then can move via plasmodesmata
  - The ***transmembrane route***
    - Across cell walls

Figure 29.4


Cell wall
Apoplastic route
Cytosol
Symplastic route
Transmembrane route
Plasmodesma
Plasma membrane
Key
Apoplast
Symplast

- The waxy **Casparian strip** blocks apoplastic transfer of minerals from cortex to vascular cylinder
  - Forces water and minerals in the apoplast to cross the plasma membrane
    - Selectively permeable!
  - Also prevents solutes in xylem from leaking back out

Figure 29.16



1 Apoplastic route
2 Symplastic route
3 Transmembrane route
4 The endodermis: controlled entry to the vascular cylinder (stele)
5 Transport in the xylem
Casparian strip
Endodermal cell
Pathway along apoplast
Pathway through symplast
Plasma membrane
Apoplastic route
Symplastic route
Root hair
Epidermis
Endodermis
Vascular cylinder (stele)
Cortex
Vessels (xylem)

# Short-Distance Transport

- Plasma membrane permeability controls short-distance movement of substances
- Active transport (low to high; energy required)
  - In plants, membrane potential is established through pumping $H^+$ by proton pumps
    - Plant cells use the energy of $H^+$ gradients to cotransport other solutes by active transport
  - In animals, membrane potential is established through pumping $Na^+$ by sodium-potassium pumps
- Passive transport (high to low; no energy)
  - **Osmosis** is the diffusion of free water across a membrane
    - Water moves through cell membrane via **aquaporins**

$$\Psi = \Psi_S + \Psi_P$$

- **Water potential** is a measurement that combines the effects of solute concentration and pressure
  - Determines the direction of movement of water
- Water flows from regions of higher water potential to regions of lower water potential!
- $\Psi_P$ = **pressure potential**
  - Equals 0 in open beaker
- $\Psi_S$ = **solute potential**
  - AKA: Osmotic potential
  - Directly proportional to its molarity
- An increase in solutes has a negative effect on water potential
  - As solute concentration increases, $\Psi_S$ becomes more negative!

# Long-Distance Transport

- Efficient long-distance transport of fluid requires **bulk flow**
  - Movement of a fluid driven by pressure
  - Occurs from higher to lower pressure
  - Independent of solute concentration
- Water and solutes move together through tracheids and vessel elements of xylem and sieve-tube elements of phloem
- Efficient movement is possible because
  - Mature tracheids and vessel elements have no cytoplasm
  - Sieve-tube elements have few organelles in cytoplasm

- **Xylem sap**, water and dissolved minerals, is transported from roots to leaves by bulk flow
  - Much faster than diffusion or active transport
- The transport of xylem sap involves **transpiration**
  - The loss of water vapor from a plant's surface
  - Increases under following conditions:

    ~Sunny ~Warm

    ~Dry ~Windy
- Transpired water is replaced as water travels up from the roots
- Transpiration and water cohesion pull water from shoots to roots!

## Transpirational Pull

- Typically, the air outside the leaf is drier
  - Has lower water potential than air inside the leaf
  - So water vapor diffuses down its water potential gradient and exits the leaf via stomata
- Negative pressure potential develops in the leaves
  - This lowers water potential
    - Water moves from high to low!
- This causes water to move up through the xylem from roots to leaves
  - The pulling effect results from the cohesive binding between water molecules

## Cohesion and adhesion

- **Cohesion** = water molecules are attracted to each other
  - Can pull column of xylem sap
- **Adhesion** = water molecules are attracted to xylem cell walls
  - Helps offset the force of gravity

- Transpirational pull depends on water’s cohesion, adhesion, and surface tension

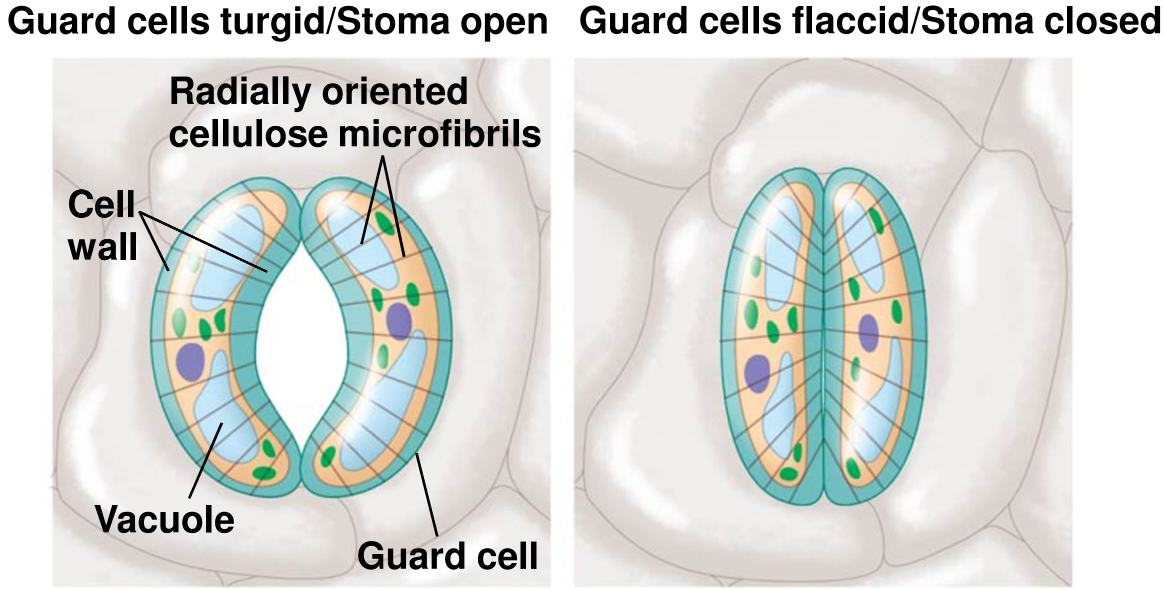
- Bulk flow is driven by a water potential difference at opposite ends of xylem tissue
- Bulk flow is driven by evaporation
  - Does NOT require energy from the plant
  - Like photosynthesis, it is solar powered
- Bulk flow differs from diffusion
  - It is driven by differences in pressure potential, not solute potential
  - It occurs in hollow dead cells, not across the membranes of living cells
  - It moves the entire solution, not just water or solutes
  - It is much faster

# Regulating Water Loss

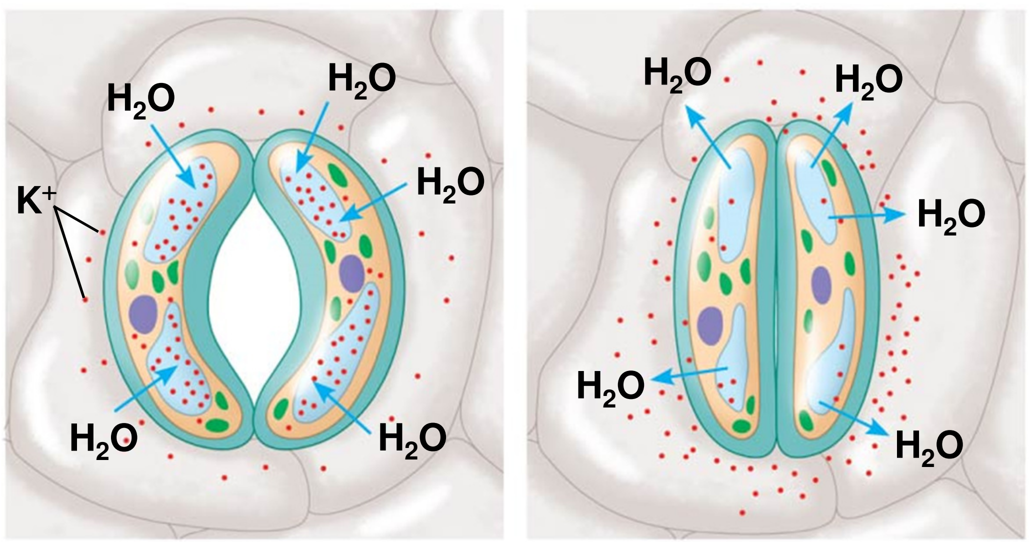
- Leaves generally have broad surface areas and high surface-to-volume ratios
  - Increases photosynthesis
  - Also increases water loss
- Waxy **cuticle** limits water loss in most of leaf
  - Most of the water lots escapes through **stomata**
- Each stoma is flanked by a pair of **guard cells**
  - Help balance water conservation with gas exchange for photosynthesis
  - Generally, stomata open during the day and close at night to minimize water loss
  - Homeostasis!

- Changes in turgor pressure open and close stomata
  - When turgid (filled with water), guard cells open stomata
  - When flaccid (lack of water), guard cells close stomata
- Changes in turgor pressure result primarily from the movement of potassium ions ($K^+$)
  - Stomata open when guard cells accumulate $K^+$
  - Stomata close when guard cells lose $K^+$, which leads to an osmotic loss of water
- The hormone **abscisic acid (ABA)** also causes the closure of stomata

Figure 29.19




(a) Changes in guard cell shape and stomatal opening and closing (surface view)




(b) Role of potassium ions ($K^+$) in stomatal opening and closing

- **Crassulacean acid metabolism (CAM) plants**
  - Stomata remain closed during the day (when hotter)
  - Gas exchange occurs at night
  - Temporal separation of steps
- **$C_4$ plants**
  - Partially close stomata on hot/dry days to conserve water
  - But sugar continues to be made through function of 2 different types of photosynthetic cells
    - Mesophyll cells
    - Bundle-sheath cells
  - Spatial separation of steps

# Unit 8
# Plant Form and Function

## Chapter 30: Reproduction and Domestication of Flowering Plants

# Angiosperm Life Cycle

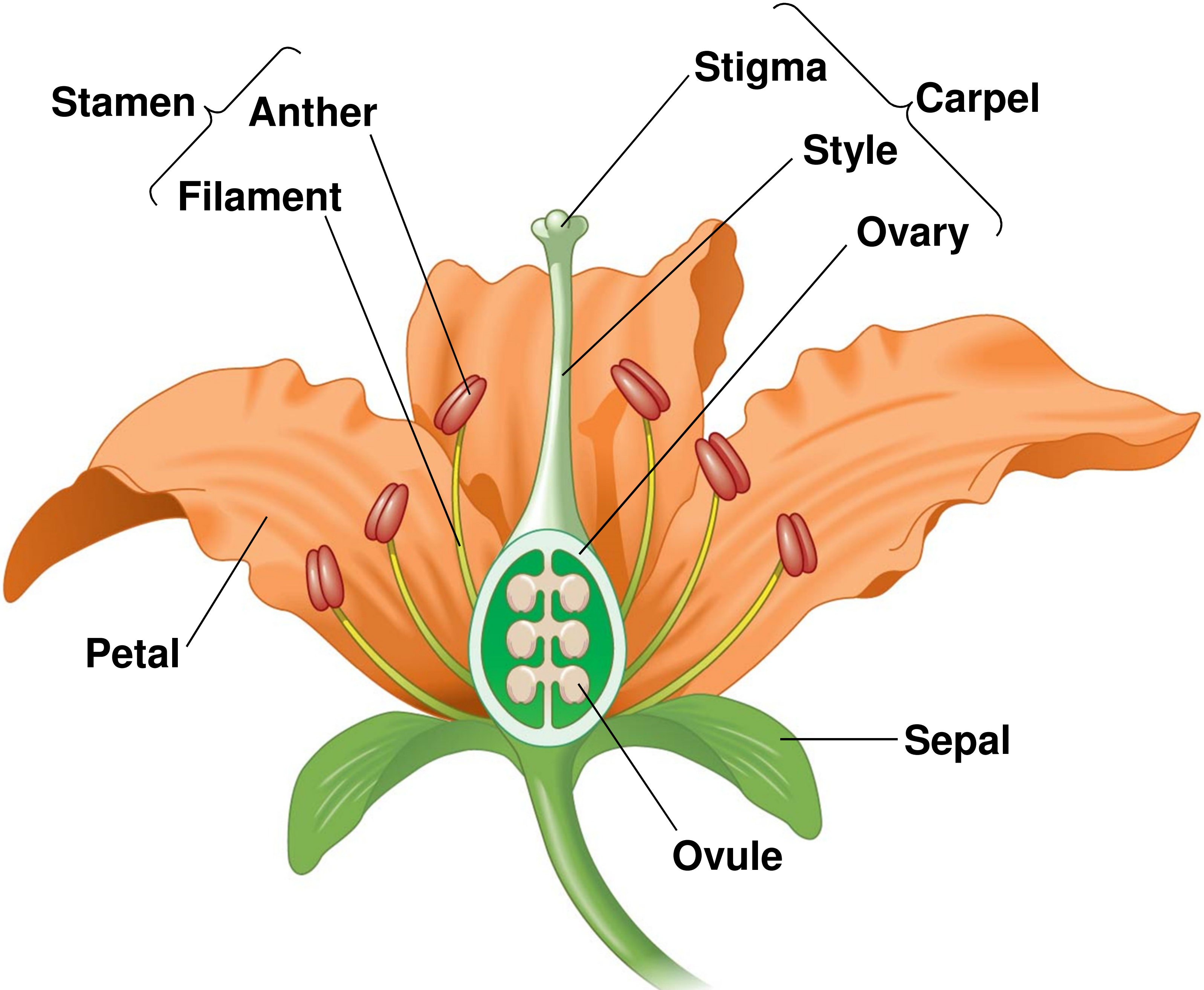
- Plant life cycles are characterized by the alternation of generations
- Diploid sporophytes (2*n*) produce spores (*n*) by meiosis
  - These grow and divide into multicellular haploid gametophytes (*n*)
- Gametophytes produce haploid gametes (*n*) by mitosis
  - Fertilization of gametes produces a sporophyte
- The sporophyte is the dominant generation in angiosperms
- The angiosperm life cycle is characterized by "three Fs": <u>F</u>lowers, Double <u>F</u>ertilization, <u>F</u>ruits

# Flower Structure and Function

- Flowers are the reproductive shoots of the angiosperm sporophyte
- Flowers are determinate shoots
  - They cease growing after flower and fruit are formed
- Flowers consist of four floral organs: **carpels**, **stamens**, **petals**, and **sepals**
  - Carpels (female parts) and stamens (male parts) are reproductive organs
  - Sepals and petals are sterile

- A single carpel or group of fused carpels is called a **pistil**
  - A carpel has a long **style** with a sticky **stigma** on which pollen may land
  - At the base of the style is an **ovary** containing one or more **ovules**
- A stamen consists of a *filament* topped by an **anther** with pollen sacs that produce pollen
- Petals are typically brightly colored to attract pollinators
- Sepals enclose and protect unopened floral buds
  - Resemble leaves

Figure 30.2


Stamen
Anther
Filament
Stigma
Carpel
Style
Ovary
Petal
Sepal
Ovule

- In angiosperms, **pollination** is the transfer of pollen from an anther to a stigma
  - Pollination can be by wind, water, or animals
  - Most angiosperms depend on insects, birds, or other animal pollinators
- Floral adaptations to attract bees include
  - Production of nectar
  - Sweet fragrance
  - Brightly colored petals
  - “Nectar guides”

# Double Fertilization

- **Double fertilization** results from the discharge of two sperm from the pollen tube into the embryo sac
  - One sperm fertilizes the egg
  - The other combines with the polar nuclei
    - Gives rise to the triploid food-storing **endosperm** ($3n$)
- Double fertilization ensures that endosperm develops only in ovules where the egg has been fertilized
- Each ovule develops into a seed
- The ovary develops into a fruit enclosing the seed(s)

- The seed enters a state of **dormancy**
  - Stops growing and slows metabolism
- Seed dormancy increases the chances that germination will occur at a time and place most advantageous to the seedling
- The breaking of seed dormancy often requires environmental cues
  - Temperature or lighting changes
  - Substantial rainfall (desert species)
  - Heat or smoke (where fires are common)
  - Chemical attacks as they pass through animal's digestive tract

# Fruit Form and Function

- Fertilization triggers hormonal changes that cause the ovary to develop into a **fruit**
  - Protects the enclosed seeds and aids in seed dispersal by wind or animals
- Fruit dispersal mechanisms include
  - Water
  - Wind
  - Animals

# Advantages and Disadvantages of Asexual Versus Sexual Reproduction

- Asexual reproduction is also called **vegetative reproduction**
- Asexual reproduction can be beneficial to a successful plant in a stable environment
  - No need for a pollinator
  - Allows plant to pass on entire genetic legacy
  - Can quickly produce multiple clones
  - Generally stronger
  - Flowering and fruiting are “expensive” in terms of resources
- However, a clone of plants is vulnerable to local extinction if there is an environmental change

- Sexual reproduction generates genetic variation that makes evolutionary adaptation possible
  - Numerous seeds compensate for odds against individual survival
  - Seeds facilitate dispersal to more distant locations
  - Seed dormancy allows growth to be suspended until environmental conditions become favorable
- However, only a fraction of seedlings survive

# Unit 8
# Plant Form and Function

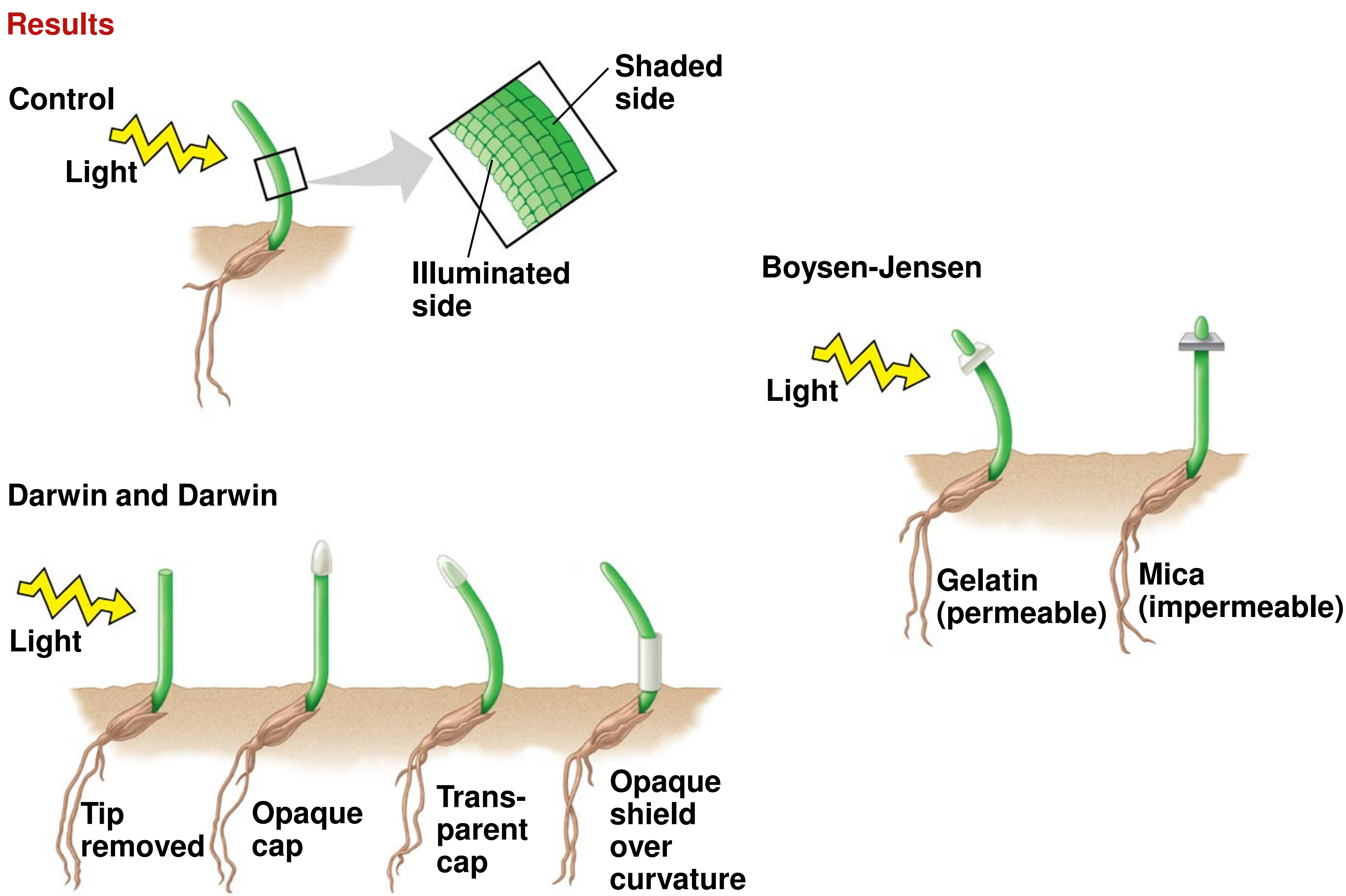
## Chapter 31: Plant Responses to Internal and External Signals

# Plant Hormones

- Plant movement toward or away from a stimulus is called a **tropism**
- The growth of a plant toward or away from light is called **phototropism**
  - Roots exhibit negative phototropism
  - Shoots exhibit positive phototropism
    - Directs shoot growth toward sunlight for photosynthesis
    - Cells on the darker side elongate faster than cells on the brighter side

- Experiments:
  - Grass seedling could bend toward light only if the tip of the coleoptile was present
    - No tip = no bending
    - Opaque cap = no bending
    - Transparent cap = bending
    - Opaque shield over curvature = bending
  - A signal was transmitted from the tip to the elongating region
    - Tip on permeable gelatin = bending
    - Tip on impermeable mica = no bending
  - Chemical was **auxin**

Figure 31.2


Results
Control
Light
Shaded side
Illuminated side
Boysen-Jensen
Light
Gelatin (permeable)
Mica (impermeable)
Darwin and Darwin
Light
Tip removed
Opaque cap
Trans-parent cap
Opaque shield over curvature

- The major classes of plant hormones include
  - **Auxin**
    - Elongation (esp shoots)
    - Inhibit axillary buds
  - **Cytokinins**
    - Cell division (esp roots)
    - Stimulate axillary bud growth
    - Slow aging of some plant organs
  - **Gibberellins**
    - Stem elongation, fruit growth, seed germination
    - Produced in young roots and leaves

- **Brassinosteroids**
    - Slow leaf abscission (leaf drop)
- **Abscisic acid (ABA)**
    - Slows growth
    - Seed dormancy and drought tolerance
- **Ethylene**
    - Fruit ripening (gas)
    - Aging (senescence)
    - Leaf abscission

# Photoreceptors

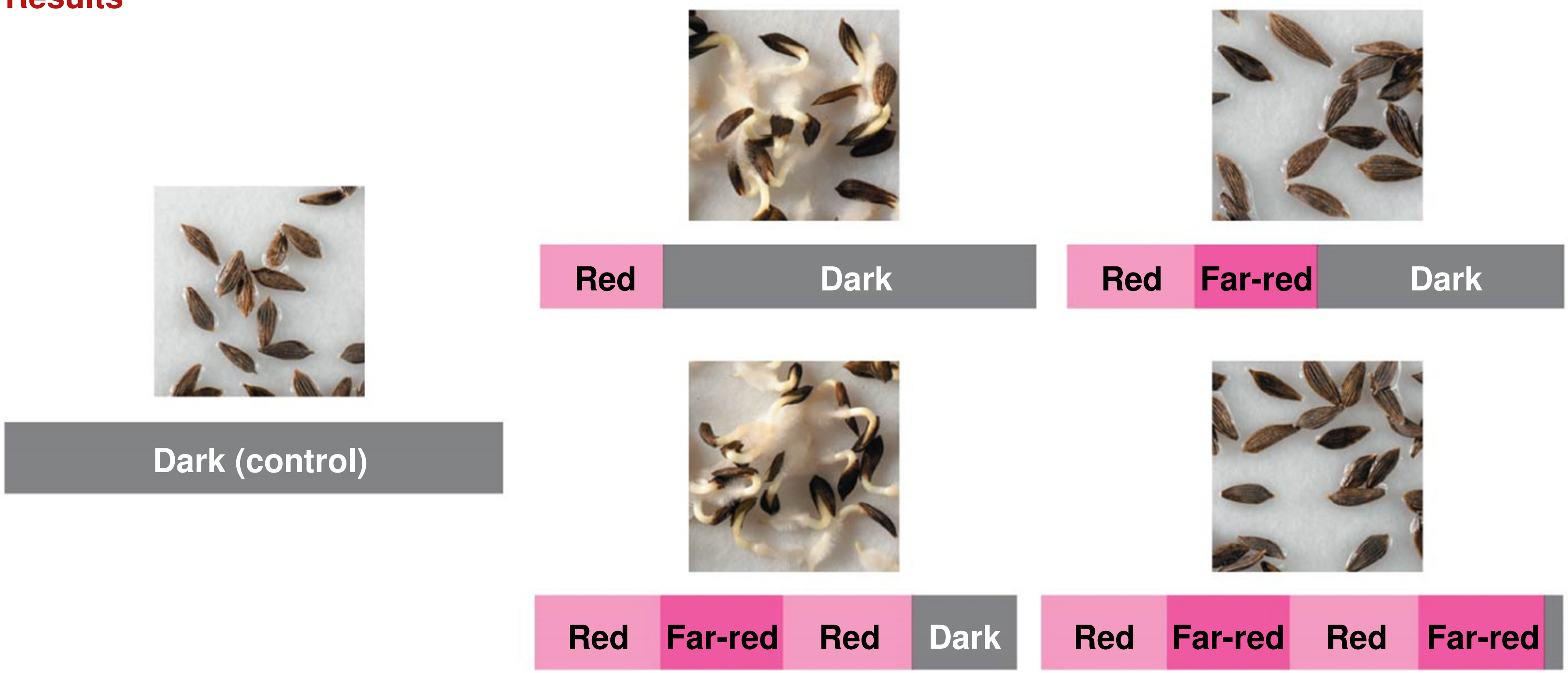
- Red and blue light are the most important colors in plant growth and development (photomorphogenesis)
- There are two major classes of light receptors:
  - **Blue-light photoreceptors**
    - Blue light initiates phototropism and stomatal opening
  - **Phytochromes**
    - Photoreceptors that absorb mostly red light
    - Regulate seed germination and shade avoidance

## Phytochromes and seed germination

- Many seeds remain dormant until light conditions are optimal
  - Red light increases germination
  - Far-red light inhibits germination
  - The final light exposure is the determining factor
    - The effects of red and far-red light are reversible
- Phytochrome conversion marks sunrise and sunset, providing the biological clock with environmental cues

Figure 31.13

**Results**

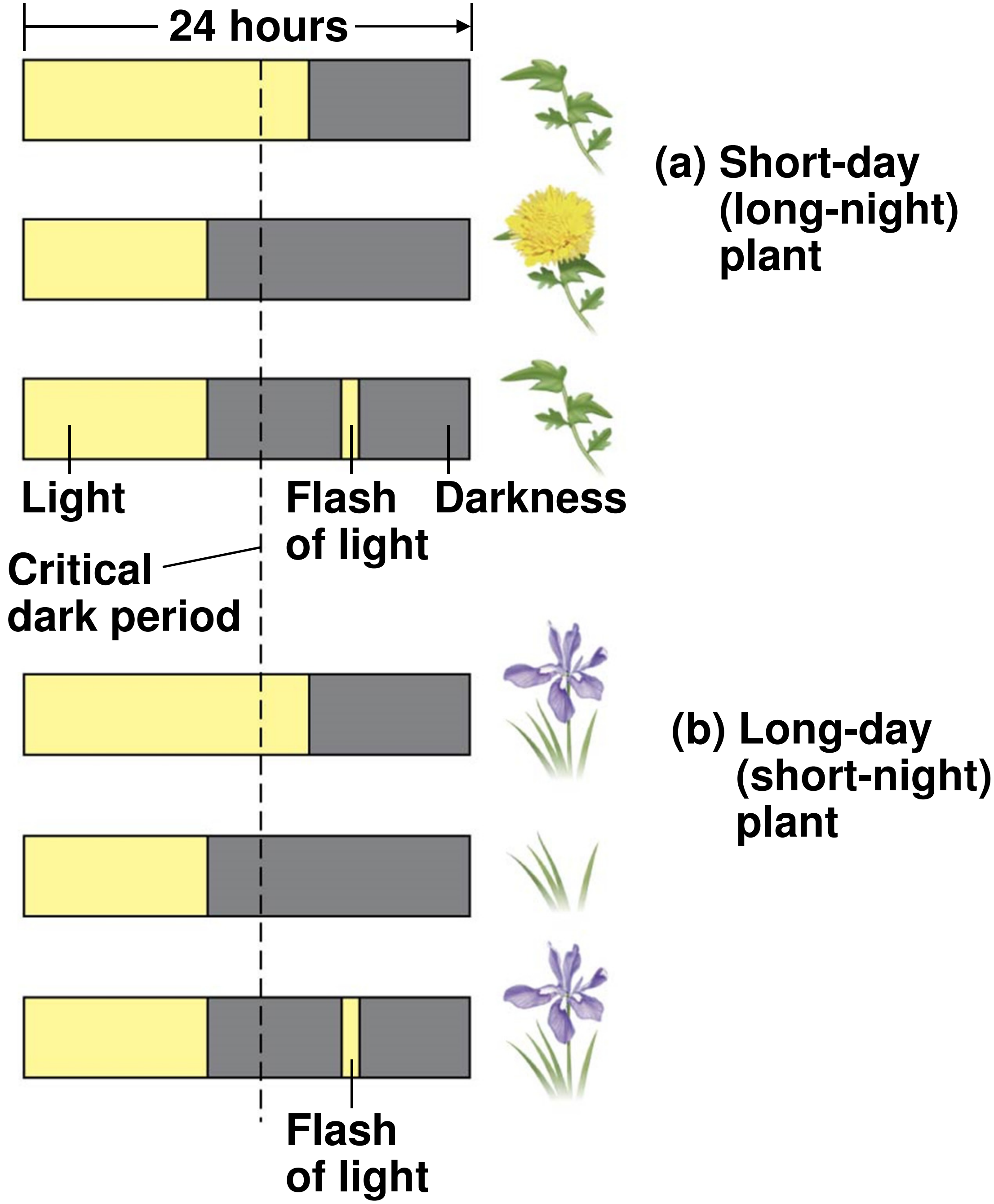


# Photoperiodism

- Seed germination, flowering, and onset and breaking of bud dormancy are all stages that usually occur at specific times of the year
- Photoperiod, the relative lengths of night and day, is the environmental stimulus plants use most often to detect the time of year
- **Photoperiodism** is a physiological response to photoperiod
  - Ex: Flowering

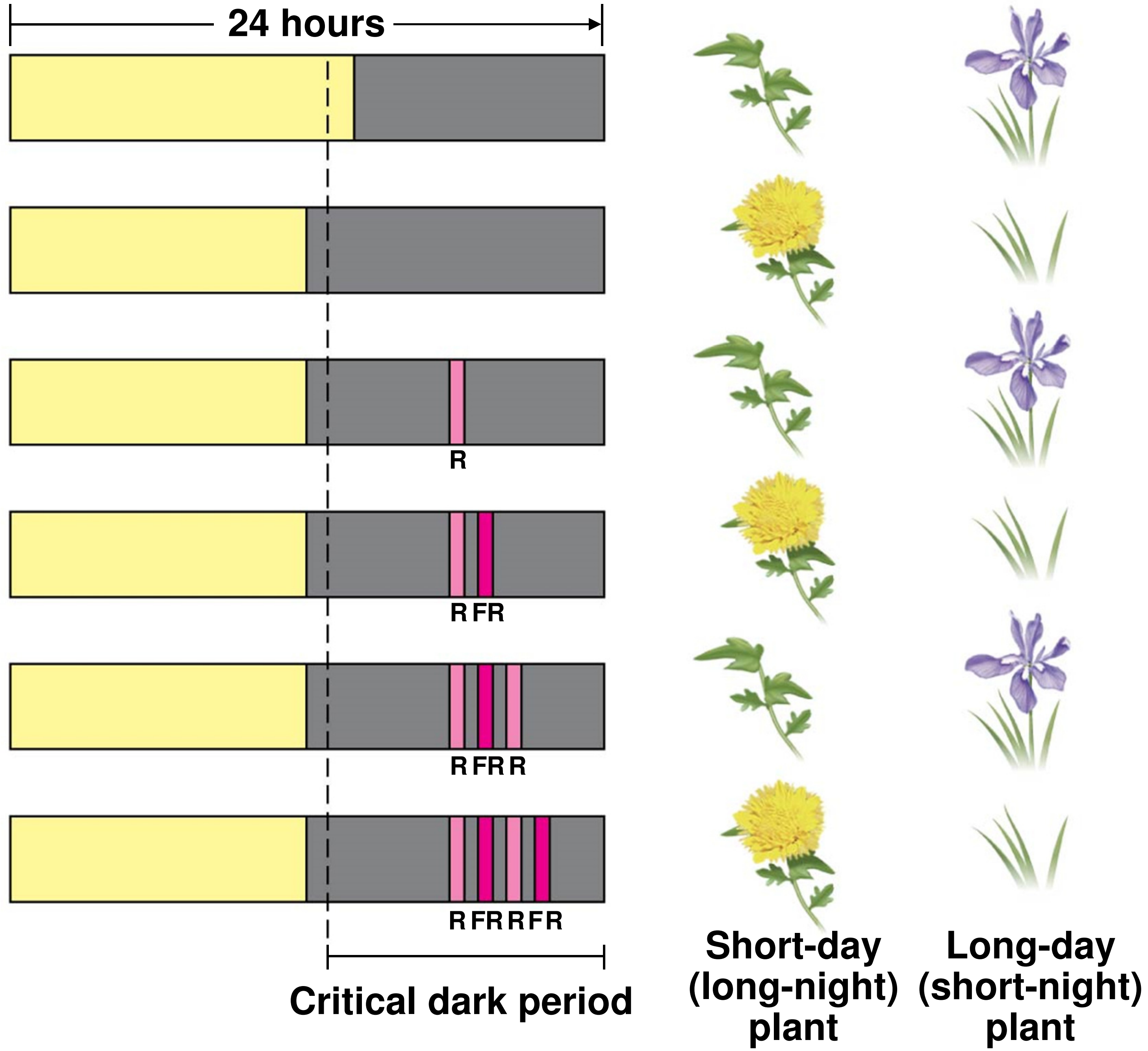
- Plants that flower when a light period is shorter than a critical length are called **short-day plants**
  - Short-day plants are really long-night plants
    - Governed by whether the critical night length sets a minimum number of hours of darkness
  - Chrysanthemums, pointsettias
- Plants that flower when a light period is longer than a certain number of hours are called **long-day plants**
  - Long-day plants are really short-night plants
    - Governed by whether the critical night length sets a maximum number of hours of darkness
  - Spinach, radishes, lettuce, irises

Figure 31.16


24 hours
Light
Flash of light
Darkness
Critical dark period
Flash of light
(a) Short-day (long-night) plant
(b) Long-day (short-night) plant

- Red light can interrupt the nighttime portion of the photoperiod
- A flash of red light followed by a flash of far-red light does not disrupt night length
- Applied to produce flowers out of season!

Figure 31.17


24 hours
R
R FR
R FR R
R FR R FR
Critical dark period
Short-day (long-night) plant
Long-day (short-night) plant

# Other Stimuli

- **Gravitropism** = Response to gravity
  - AKA **geotropism**
  - Ensures roots grow down (+) into soil and shoot grows up (-) toward light, regardless of how the seed is oriented when it lands
  - Plants may detect gravity by the settling of **statoliths**
- **Thigmotropism** = growth in response to touch
  - It occurs in vines and other climbing plants
  - Some plants folds their leaflets and collapse in response to touch

# Response to Herbivores and Pathogens

- Plants counter excessive herbivory with
  - Physical defenses
    - Thorns and trichomes
  - Chemical defenses
    - Distasteful or toxic compounds
  - “Recruit” predatory animals that help defend against specific herbivores

- Plants defend against pathogens through
  - The **hypersensitive response**
    - Causes localized cell and tissue death near the infection site
    - Induces production of proteins that attack the specific pathogen
  - **Systemic acquired resistance**
    - Causes plant-wide expression of defense genes
    - Protects against a diversity of pathogens
      - Nonspecific
    - Provides a long-lasting response